

AMENDMENTS TO THE CLAIMS

Claims remaining in the application are as follows:

1. (Canceled)

2. (Currently Amended): A method for off-line Personal Identification Number (PIN) verification using a smart card accessed on an off-line terminal, the method according to Claim 1 further comprising:

creating a unique secret key for an enrolled smart card using a card issuer private key;
generating signatures on an entered PIN using the unique key, the signatures being
verifiable by the smart card and/or the terminal;

entering an initialization PIN to the smart card at an enrollment system;

generating a reference signature on the initialization PIN using the unique key and the initialization PIN;

storing the reference signature on the smart card; and

discarding the PIN after signature generation.

3. (Original): The method according to Claim 2 further comprising:

communicatively connecting the smart card to an off-line terminal;

receiving a transaction PIN' at the off-line terminal;

generating a candidate signature on the transaction PIN' using the unique key; and

verifying the candidate signature against the reference signature.

4. (Original): The method according to Claim 3 further comprising:

for a verified candidate signature, unlocking the smart card to enable a transaction.

5. (Currently Amended): A method for off-line Personal Identification Number (PIN) verification using a smart card accessed on an off-line terminal, the method according to Claim 1 further comprising:

creating a unique secret key for an enrolled smart card using a card issuer private key;

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generating signatures on an entered PIN using the unique key, the signatures being verifiable by the smart card and/or the terminal;

entering an initialization PIN to the smart card at an enrollment system;
generating the unique secret key based on the private key;
generating at least one signature precursor from the unique secret key;
storing the at least one signature precursor on the smart card; and
discarding the PIN and the unique secret key.

6. (Original): The method according to Claim 5 further comprising:
communicatively connecting the smart card to an off-line terminal;
receiving a transaction PIN' at the off-line terminal;
communicating the transaction PIN' and an off-line terminal-generated random number to the smart card;
generating a signature on the smart card based on the transaction PIN', the at least one signature precursor, and the random number; and
verifying the signature at the off-line terminal.

7. (Canceled)

8. (Currently Amended): A method for off-line Personal Identification Number (PIN) verification using a smart card accessed on an off-line terminal, the method according to Claim 7 further comprising:

using PIN verification to unlock a smart card;

enabling the unlocked smart card to perform a selected function in a financial transaction for a cardholder;

creating a unique secret key for an enrolled smart card using a card issuer private key;

generating signatures on an entered PIN using the unique key, the signatures being verifiable by the smart card and/or the terminal;

computing at an enrollment system a secret key u that is unique to the smart card using an equation of the form:

$$u = I^d(\text{mod } N),$$

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where I is an entity-identifier, d is a private exponent in an RSA system known only to the enrollment system, and N is an RSA system modulus;
 computing at the enrollment system a signature precursor A using an equation of the form:

$$A = \text{PIN}^{-1} \cdot u \pmod{N},$$

where PIN is an enrollment Personal Identification Number (PIN);
 storing on the smart card the signature precursor A , a public exponent e , the modulus N , and the entity-identifier I ;
 computing at the smart card a digital signature component t using an equation of the form:

$$t = \text{PIN}^e \pmod{N};$$

hashing at the smart card a function $Z = h(t, \text{PIN}, I)$ to compute a reference signature of the form:

$$S = u \cdot \text{PIN}^Z \pmod{N},$$

where $h()$ is a hashing algorithm;
 storing the reference signature S on the smart card; and
 crasing from the smart card the enrollment PIN , the secret key u , the digital signature component t , and function Z .

9. (Original): The method according to Claim 8 further comprising:
 communicatively connecting a smart card to a transaction terminal;
 receiving at the transaction terminal a transaction PIN' ;
 computing at the smart card a transaction secret key u' , a transaction digital signature component t' , and a transaction function Z' , using respective equations of the form:

$$u' = \text{PIN}' \cdot A \pmod{N},$$

$$t' = (\text{PIN}')^e \pmod{N}, \text{ and}$$

$$Z' = h(t', \text{PIN}', I);$$

computing at the smart card a candidate signature S' using an equation of the form:

$$S' = u' \cdot (\text{PIN}')^{Z'} \pmod{N};$$

for $S' = S$ so that $\text{PIN}' = \text{PIN}$, verifying PIN' ; and

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unlocking the smart card for a transaction for a verified PIN'.

10. (Currently Amended): The method according to Claim 7 8 wherein:
the smart card contains sufficient information to verify an entered PIN prior to
proceeding to a transaction; and

the PIN is passed from a transaction terminal to the smart card and remaining
verification operations are performed on the smart card.

11. (Currently Amended): A method for off-line Personal Identification Number (PIN) verification using a smart card accessed on an off-line terminal, the method according to Claim 1 further comprising:

creating a unique secret key for an enrolled smart card using a card issuer private key;
generating signatures on an entered PIN using the unique key, the signatures being
verifiable by the smart card and/or the terminal; and

enabling a financial terminal to perform a challenge-response protocol to determine
whether the smart card and an entered transaction PIN' are valid for a financial
transaction to proceed.

12. (Original): The method according to Claim 11 further comprising:
computing at an enrollment system a secret key u that is unique to the smart card using
an equation of the form:

$$u = I^d \pmod{N},$$

where I is an entity-identifier, d is a private exponent in an RSA system known
only to the enrollment system, and N is an RSA system modulus;

transferring from the enrollment system to the smart card the secret key u , the identity-
identifier I , a public exponent e , and the modulus N , and an entity-selected
Personal Identification Number (PIN);

computing at the smart card a signature precursor A using an equation of the form:

$$A = \text{PIN}^{-1} \cdot u \pmod{N}; \text{ and}$$

storing on the smart card the signature precursor A , a public exponent e , the modulus
 N , and the entity-identifier I .

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13. (Currently Amended): The method according to Claim 12 further comprising:
 communicatively connecting a smart card to a transaction terminal;
 receiving at the transaction terminal a the transaction PIN';
 transferring from the transaction terminal to the smart card a random number r_t
 generated at the transaction terminal, and an entity-entered PIN';
 waiting at the transaction terminal for a response;
 generating at the smart card a random number r_c ;
 computing at the smart card a transaction digital signature component t , a transaction
 secret key u' , a hash function Z , and a signature S using respective equations of
 the form:

$$t = (r_t \cdot r_c \cdot \text{PIN}')^c \pmod{N},$$

$$u' = \text{PIN}' \cdot A \pmod{N},$$

$$Z = h(t, \text{PIN}', I)$$

$$S = u' \cdot (r_t \cdot r_c \cdot \text{PIN}')^Z \pmod{N},$$

where $h()$ is a hashing algorithm;

transferring from the smart card to the transaction terminal the signature S and the
 digital signature component t ;
 computing at the transaction terminal values $Z = h(t, \text{PIN}', I)$; $C = I \cdot t^Z \pmod{N}$; and
 $S^c \pmod{N}$;
 determining at the transaction terminal whether $S^c = C \pmod{N}$, and
 if so, verifying the smart card-generated signature S , affirming that PIN' is equal to
 PIN.

14. (Currently Amended): The method according to Claim 11 wherein:
 the smart card on PIN verification performs operations that verify smart card
 possession of a secret key created and installed at enrollment of the card, and
 that verify that a the transaction PIN' entered by an entity matches the PIN at
 enrollment;
 the verification operations are performed without having the enrollment PIN stored on
 the smart card; and

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verification occurs without the smart card revealing the secret key to the transaction terminal.

15. (Currently Amended): The method according to Claim 4 & 8 wherein: the card issuer private key is an RSA (Rivest, Shamir, and Adelman Public Key Cryptosystem) key.

16. (Original): A data security apparatus comprising:
a smart card capable of off-line Personal Identification Number (PIN) verification comprising:
an interface capable of communicating with an off-line terminal and an enrollment system;
a processor coupled to the interface; and
a memory coupled to the processor and having a computable readable program code embodied therein that executes off-line PIN verification based on creating a unique secret key for an enrolled smart card using a card issuer private key and generating signatures on an entered PIN using the unique key, the signatures being verifiable by the smart card and/or the off-line terminal.

17. (Original): The apparatus according to Claim 16 wherein the memory further comprises:
a computable readable program code capable of causing the processor to receive an initialization PIN from the enrollment system;
a computable readable program code capable of causing the processor to generate a reference signature on the initialization PIN using the unique key;
a computable readable program code capable of causing the processor to store the reference signature on the smart card that is generated from the PIN; and
a computable readable program code capable of causing the processor to discard the PIN without storage after signature generation.

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18. (Original): The apparatus according to Claim 17 wherein the memory further comprises:

- a computable readable program code capable of causing the processor to receive a transaction PIN' via the off-line terminal;
- a computable readable program code capable of causing the processor to generate a candidate signature on the transaction PIN' using the unique key; and
- a computable readable program code capable of causing the processor to verify the candidate signature against the reference signature.

19. (Original): The apparatus according to Claim 18 wherein the memory further comprises:

- a computable readable program code capable of causing the processor to enable a transaction for a verified candidate signature.

20. (Original): The apparatus according to Claim 16 wherein the memory further comprises:

- a computable readable program code capable of causing the processor to receive an initialization PIN from the enrollment system;
- a computable readable program code capable of causing the processor to generate the unique secret key based on the private key and the initialization PIN;
- a computable readable program code capable of causing the processor to generate at least one signature precursor from the unique secret key;
- a computable readable program code capable of causing the processor to store the at least one signature precursor in the memory; and
- a computable readable program code capable of causing the processor to erase the PIN and the unique secret key without storage.

21. (Original): The apparatus according to Claim 20 wherein the memory further comprises:

- a computable readable program code capable of causing the processor to receive a transaction PDN' and a random number from the off-line terminal;

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a computable readable program code capable of causing the processor to generate a signature based on the transaction PIN', the at least one signature precursor, and the random number; and

a computable readable program code capable of causing the processor to send the signature to the off-line terminal for verification.

22. (Original): The apparatus according to Claim 16 wherein the memory further comprises:

a computable readable program code capable of causing the processor to receive from an enrollment system a secret key u that is unique to the smart card and a signature precursor A , the secret key u being defined by an equation of the form:

$$u = I^d \pmod{N},$$

where I is an entity-identifier, d is a private exponent in an RSA system known only to the enrollment system, and N is an RSA system modulus, the signature precursor A being defined by an equation of the form:

$$A = \text{PIN}^{-1} \cdot u \pmod{N},$$

where PIN is an enrollment Personal Identification Number (PIN);

a computable readable program code capable of causing the processor to store in the memory the signature precursor A , a public exponent e , the modulus N , and the entity-identifier I ;

a computable readable program code capable of causing the processor to compute a digital signature component t using an equation of the form:

$$t = \text{PIN}^e \pmod{N};$$

a computable readable program code capable of causing the processor to hash a function $Z = h(t, \text{PIN}, I)$ to compute a reference signature of the form:

$$S = u \cdot \text{PIN}^Z \pmod{N},$$

where $h()$ is a hashing algorithm;

a computable readable program code capable of causing the processor to store the reference signature S in the memory; and

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a computable readable program code capable of causing the processor to erase the enrollment PIN, the secret key u , the digital signature component t , and function Z from memory.

23. (Original): The apparatus according to Claim 22 wherein the memory further comprises:

a computable readable program code capable of causing the processor to receive from the transaction terminal a transaction PIN';

a computable readable program code capable of causing the processor to compute a transaction secret key u' , a transaction digital signature component t' , and a transaction function Z' using respective equations of the form:

$$u' = \text{PIN}' \cdot A(\text{mod } N),$$

$$t' = (\text{PIN}')^e(\text{mod } N), \text{ and}$$

$$Z' = h(t', \text{PIN}', 1);$$

a computable readable program code capable of causing the processor to compute a candidate signature S' using an equation of the form:

$$S' = u' \cdot (\text{PIN}')^{Z'}(\text{mod } N);$$

a computable readable program code operative for $S' = S$ so that $\text{PIN}' = \text{PIN}$ and capable of causing the processor to verify PIN' ; and

a computable readable program code capable of causing the processor to enable a transaction for a verified PIN' .

24. (Original): The apparatus according to Claim 16 wherein the memory further comprises:

a computable readable program code capable of causing the processor to receive from an enrollment system a secret key u that is unique to the smart card, the identity-identifier I , a public exponent e , and the modulus N , and an entity-selected Personal Identification Number (PIN), the secret key u being defined by an equation of the form:

$$u = I^d(\text{mod } N),$$

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where I is an entity-identifier, d is a private exponent in an RSA system known only to the enrollment system, and N is an RSA system modulus;

a computable readable program code capable of causing the processor to compute a signature precursor A using an equation of the form:

$$A = \text{PIN}^{-1} \cdot u \pmod{N};$$

a computable readable program code capable of causing the processor to generate a random number r_c ; and

a computable readable program code capable of causing the processor to store in the memory the signature precursor A , a public exponent e , the modulus N , and the entity-identifier I .

25. (Original): The apparatus according to Claim 24 wherein the memory further comprises:

a computable readable program code capable of causing the processor to receive from the transaction terminal a random number r_t generated at the transaction terminal, and an entity-entered PIN' , and a random number r_c generated in the smart card;

a computable readable program code capable of causing the processor to compute a transaction digital signature component t , a transaction secret key u' , a hash function Z , and a signature S , using respective equations of the form:

$$t = (r_t \cdot r_c \cdot \text{PIN}')^e \pmod{N},$$

$$u' = \text{PIN}' \cdot A \pmod{N},$$

$$Z = h(t, \text{PIN}', I)$$

$$S = u' \cdot (r_t \cdot r_c \cdot \text{PIN}')^Z \pmod{N},$$

where $h()$ is a hashing algorithm;

a computable readable program code capable of causing the processor to transfer from the smart card to the transaction terminal the signature S' and the digital signature component t ;

a computable readable program code capable of causing the processor to compute at the transaction terminal values $Z = h(t, \text{PIN}', I)$; $C = I \cdot t^Z \pmod{N}$; and $S^e \pmod{N}$; and

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a computable readable program code capable of causing the processor to determine at the transaction terminal whether $S^c = C(\text{mod } N)$, and, if so, verify the signature S , affirming that PIN' is equal to PIN .

26. (Original): The apparatus according to Claim 16 wherein:
the card issuer private key is an RSA (Rivest, Shamir, and Adelman Public Key Cryptosystem) key.

27. (Original): A data security apparatus comprising:
an enrollment system capable of usage for off-line Personal Identification Number (PIN) verification using a smart card accessed on an off-line terminal, the enrollment system comprising:
a communication interface capable of communicating with a terminal configured to accept a smart card that executes off-line Personal Identification Number (PIN) verification;
a processor coupled to the communication interface; and
a memory coupled to the processor and having a computable readable program code embodied therein capable of causing the processor to initialize and personalize a smart card for usage in creating a unique secret key for an enrolled smart card using a card issuer private key, and generating signatures on an entered PIN using the unique key, the signatures being verifiable by the smart card and/or the terminal.

28. (Original): The apparatus according to Claim 27 wherein the memory further comprises:

a computable readable program code capable of causing the processor to compute a secret key u that is unique to the smart card using an equation of the form:

$$u = I^d(\text{mod } N),$$

where I is an entity-identifier, d is a private exponent in an RSA system known only to the enrollment system, and N is an RSA system modulus;

a computable readable program code capable of causing the processor to compute a signature precursor A using an equation of the form:

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$$A = \text{PIN}^{-1} \cdot u(\text{mod } N),$$

where PIN is an enrollment Personal Identification Number (PIN); transmitting to a smart card for computation and storage the signature precursor A, a public exponent e, the modulus N, and the entity-identifier I, the smart card being capable of computing a digital signature component t using an equation of the form:

$$t = \text{PIN}^e(\text{mod } N);$$

hashing at the smart card a function $Z=h(t, \text{PIN}, I)$ to compute a reference signature of the form:

$$S = u \cdot \text{PIN}^Z(\text{mod } N),$$

where h() is a hashing algorithm, storing the reference signature S; and erasing the enrollment PIN, the secret key u, the digital signature component t, and function Z.

29. (Original): The apparatus according to Claim 28 wherein the memory further comprises:

a computable readable program code capable of causing the processor to compute a secret key u that is unique to the smart card using an equation of the form:

$$u = I^d(\text{mod } N),$$

where I is an entity-identifier, d is a private exponent in an RSA system known only to the enrollment system, and N is an RSA system modulus; transferring to the smart card the secret key u, the identity-identifier I, a public exponent e, and the modulus N, and an entity-selected Personal Identification Number (PIN), the smart card being capable of computing at the smart card a signature precursor A using an equation of the form:

$$A = \text{PIN}^{-1} \cdot u(\text{mod } N); \text{ and}$$

storing the signature precursor A, a public exponent e, the modulus N, and the entity-identifier I.

30. (Original): A data security apparatus comprising:

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30. (Original): A data security apparatus comprising:
an off-line terminal capable of usage for off-line Personal Identification Number (PIN)
verification using a smart card, the off-line terminal comprising:
a communication interface capable of accepting and communicating with a
smart card that executes off-line Personal Identification Number (PIN)
verification;
a processor coupled to the communication interface; and
a memory coupled to the processor and having a computable readable program
code embodied therein capable of causing the processor to interact with
the smart card to verify an entity-entered PIN using a signature
generated on a reference PIN, the signature being generated based on a
unique secret key of an enrolled smart card derived from a card issuer
private key.

31. (Original): The apparatus according to Claim 30 wherein the memory
further comprises:
a computable readable program code capable of causing the processor to communicate
with the smart card;
a computable readable program code capable of causing the processor to receive a
transaction PIN'; and
a computable readable program code capable of causing the processor to operate in
conjunction with the smart card to generate a candidate signature on the
transaction PIN' using the unique key, and verify the candidate signature
against a reference signature.

32. (Original): The apparatus according to Claim 30 wherein the memory
further comprises:
a computable readable program code capable of causing the processor to communicate
with the smart card;
a computable readable program code capable of causing the processor to receive a
transaction PIN';

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a computable readable program code capable of causing the processor to generate a random number;

a computable readable program code capable of causing the processor to communicate the transaction PIN', and the random number to the smart card; and

a computable readable program code capable of causing the processor to operate in conjunction with the smart card to generate a signature based on the transaction PIN', the at least one signature precursor, and the random number; and verify the signature.

33. (Original): The apparatus according to Claim 30 wherein the memory further comprises:

a computable readable program code capable of causing the processor to communicate with the smart card;

a computable readable program code capable of causing the processor to receive a transaction PIN'; and

a computable readable program code capable of causing the processor to operate in conjunction with the smart card to compute a transaction secret key u' , a transaction digital signature component t' , a transaction function Z' , and a candidate signature S' using respective equations of the form:

$$u' = \text{PIN}' \cdot A(\text{mod } N),$$

$$t' = (\text{PIN}')^a(\text{mod } N),$$

$$Z' = h(t', \text{PIN}', I); \text{ and}$$

$$S' = u' \cdot (\text{PIN}')^{Z'}(\text{mod } N), \text{ and verify whether } S' = S \text{ so that } \text{PIN}' = \text{PIN}, \text{ verifying PIN'.$$

34. (Original): The apparatus according to Claim 30 wherein the memory further comprises:

a computable readable program code capable of causing the processor to communicate with the smart card;

a computable readable program code capable of causing the processor to receive a transaction PIN';

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a computable readable program code capable of causing the processor to transfer to the smart card a random number r_t generated at the transaction terminal, and the transaction PIN';

a computable readable program code capable of causing the processor to wait at the transaction terminal for a response;

a computable readable program code capable of causing the processor to operate in conjunction with the smart card to generate a random number r_c ; and

a computable readable program code capable of causing the processor to operate in conjunction with the smart card to compute a transaction digital signature component t , a transaction secret key u' , a hash function Z , and signatures S and C , using respective equations of the form:

$$t = (r_t \cdot r_c \cdot \text{PIN}')^e \pmod{N},$$

$$u' = \text{PIN}' \cdot A \pmod{N},$$

$$Z = h(t, \text{PIN}', I),$$

$$S = u' \cdot (r_t \cdot r_c \cdot \text{PIN}')^Z \pmod{N},$$

$$C = I \cdot t^Z \pmod{N}$$

where $h()$ is a hashing algorithm, and determining at the transaction terminal whether $S^e = C \pmod{N}$, and if so, verifying the signature S , affirming that PIN' is equal to PIN .

35. (Original): The apparatus according to Claim 30 wherein:
the card issuer private key is an RSA (Rivest, Shamir, and Adelman Public Key Cryptosystem) key.

36. (Currently Amended): A transaction system comprising:
a network;
a plurality of servers and/or hosts mutually coupled to the network;
a plurality of terminals capable of communicative coupling to the servers via the network and capable of off-line PIN verification;
a plurality of smart cards capable of enrollment in the transaction system and capable of insertion into the terminals for performing transactions; and

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a plurality of processors distributed among the smart cards, the servers, and/or the terminals, at least one of the processors being capable of performing a method for off-line Personal Identification Number (PIN) verification comprising:
creating a unique secret key for an enrolled smart card using a card issuer private key; and
generating signatures on an entered PIN using the unique key, the signatures being verifiable by the smart card and/or the terminal;
entering an initialization PIN to the smart card at an enrollment system;
generating a reference signature on the initialization PIN using the unique key and the initialization PIN;
storing the reference signature on the smart card; and
discarding the PIN after signature generation.

37. (Currently Amended): A transaction system comprising:
means for verifying a Personal Identification Number (PIN) using a smart card accessed on an off-line terminal;
means for creating a unique secret key for an enrolled smart card using a card issuer private key; and
means for generating signatures on an entered PIN using the unique key, the signatures being verifiable by the smart card and/or the terminal;
means for entering an initialization PIN to the smart card at an enrollment system;
means for generating a reference signature on the initialization PIN using the unique key and the initialization PIN;
means for storing the reference signature on the smart card; and
means for discarding the PIN after signature generation.

38. (New): A transaction system comprising:
a network;
a plurality of servers and/or hosts mutually coupled to the network;
a plurality of terminals capable of communicative coupling to the servers via the network and capable of off-line PIN verification;

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a plurality of smart cards capable of enrollment in the transaction system and capable of insertion into the terminals for performing transactions; and
a plurality of processors distributed among the smart cards, the servers, and/or the terminals, at least one of the processors being capable of performing a method for off-line Personal Identification Number (PIN) verification comprising:
creating a unique secret key for an enrolled smart card using a card issuer private key;
generating signatures on an entered PIN using the unique key, the signatures being verifiable by the smart card and/or the terminal;
entering an initialization PIN to the smart card at an enrollment system;
generating the unique secret key based on the private key;
generating at least one signature precursor from the unique secret key;
storing the at least one signature precursor on the smart card; and
discarding the PIN and the unique secret key.

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